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AUTHOR(S) J. D. Ready, T-4

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Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FOURIER TRANSFORM SPECTROSCOPY OF CIRCUMSTELLAR ENVELOPES

J. J. Keady

Theoretical Division, MS B212

Los Alamos National Laboratory

Los Alamos, NM 87545

In the dusty circumstellar envelopes that sometimes occur around carbon-rich stars, the surface chemistry is very active (Cernicharo et al. 1987). The circumstellar dust, one carbon compound thought to have condensed near the stellar photosphere (Ridgway and Keady, 1988), plays several roles.

The grains are efficiently accelerated away from the star by radiation pressure and drag along the gas. In addition to providing a possibly catalytic environment for the grain-surface chemistry, the grains' large radiative opacity effectively shield the outflowing gas near the star from the ambient interstellar ultraviolet radiation field. Eventually, at great enough distance from the star, the shielding becomes ineffective, and the ambient radiation field induces photolysis and/or molecule chemistry (Glassgold et al. 1986).

Historically, a great deal of our knowledge about circumstellar envelope has resulted from microwave spectroscopy. Infrared FTS spectroscopy augments the microwave techniques in several regards. The infrared band gap typically encompasses many fine-structure or considerable range of rotational and vibrational excitations after summing a considerable range of the circumstellar envelope. Molecules such as C_2H_2 , C_2 , CH_3^+ and CH_2^+ lacking a permanent dipole moment cannot be probed by microwave transition and are accessible only in the infrared. Other species are bright enough so that now the technique of high resolution infrared spectroscopy can be used to study the properties of the circumstellar envelope.

$\times 10^5$ Fourier Transform Spectroscopy (FTS) from 1.6 to 11 microns, indicate for the prototypical star, IRC + 10216, these ground-based observations see strong absorption in the various infrared bands of C_2H_2 and CO (Keady, 1987; Keady, Hall, Ridgway, 1988), among other molecules. Owing to the hydrodynamic expansion, terminal expansion velocity (11 km/s), the lines show considerable broadening and shifting. Analysis of these broadened spectra indicates the absorption occurs over a considerable place in distance from $(R_s = 6.67 \cdot 10^{13} \text{ cm}$) to $(1000 R_s)$. A considerable range of temperature detected away from the star is also indicated: $10 < T_{\text{K}} < 2000$. In the v_2 C_2H_2 fundamental lines with rotational quantum number up to $J = 50$ are seen.

High resolution 2 μm observations reveal absorption by the ethynyl (C_3H) radical showing fundamentally different behavior (Keady and Hinkley, 1988). The lines are narrow and show no evidence of accelerating gas, only gas at 11 km/s expansion velocity. Only a few lines in various branches of the Σ II band are seen rotational quantum number $N > 10$, indicating a very limited range of rotational excitation. In fact, spectrum synthesis calculations indicate a rotational temperature of 12.5 K for the C_3H gas. Depending on the temperature, molecular equilibrium calculations indicate that C_3H , as well as C_2H_2 , can be an important constituent of carbon-star photo-phores. However, the behavior of the C_3H line indicate that the observed gas is not formed in or near the photosphere and swept away for the star, but instead suddenly appears at some distance from the star. Microwave observations indicate much of the emission takes place at $\sim 1000 R_s$. Simple models of C_3H production by acetylene photolysis provide a reasonable description of the observed behavior of the C_3H transition.

Calculations also indicate that the acetylene cation, $C_2H_3^+$, is an important candidate in the photolytic process. This opens the door for ion-process chemistry and the calculation further indicate that C_3H is an indirect product

of the resultant ion-molecule chemistry. Recent 5 μm FTS observations have detected the C₃H asymmetric stretch (Heckler, Keady, and Bernath, 1988). The R and P branch transitions show no evidence for accelerating warm ($T > 100$ K) gas. Analysis of these profiles indicates a range of temperature (90 $< T < 10$ K) comparison with other molecular data suggests a location exceeding 10^6 cm above the C₃H source. The derived abundance and location are in qualitative agreement with recent modelling (Glasgold, 1988) of the expected ion-molecule chemistry.

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